



# Air quality forecasts using the NASA GEOS model: A unified tool from local to global scales

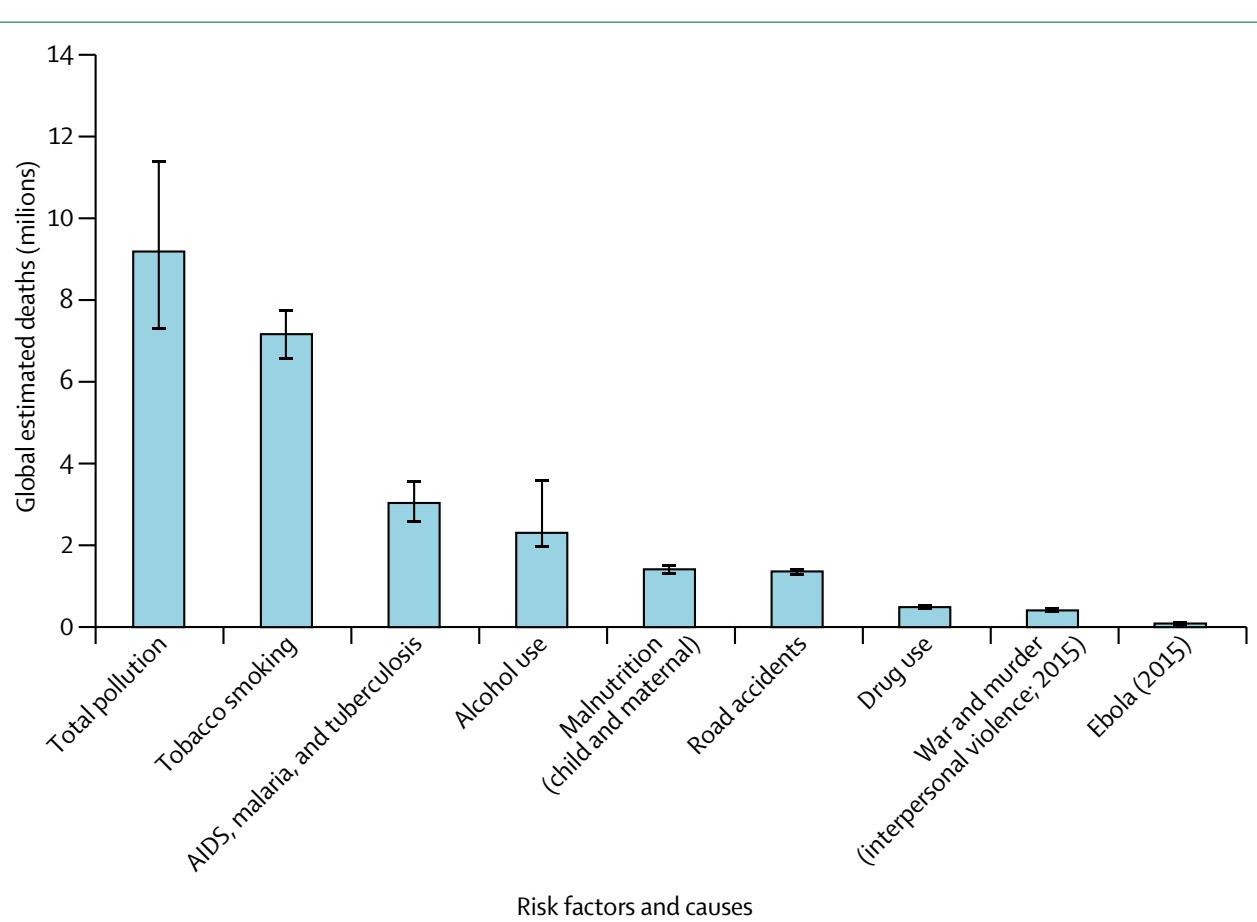
K. Emma Knowland  
(USRA/GESTAR, GMAO)



In collaboration with  
GMAO: Christoph Keller, J. Eric Nielsen, Clara Orbe, Lesley Ott,  
Steven Pawson, Emily Saunders

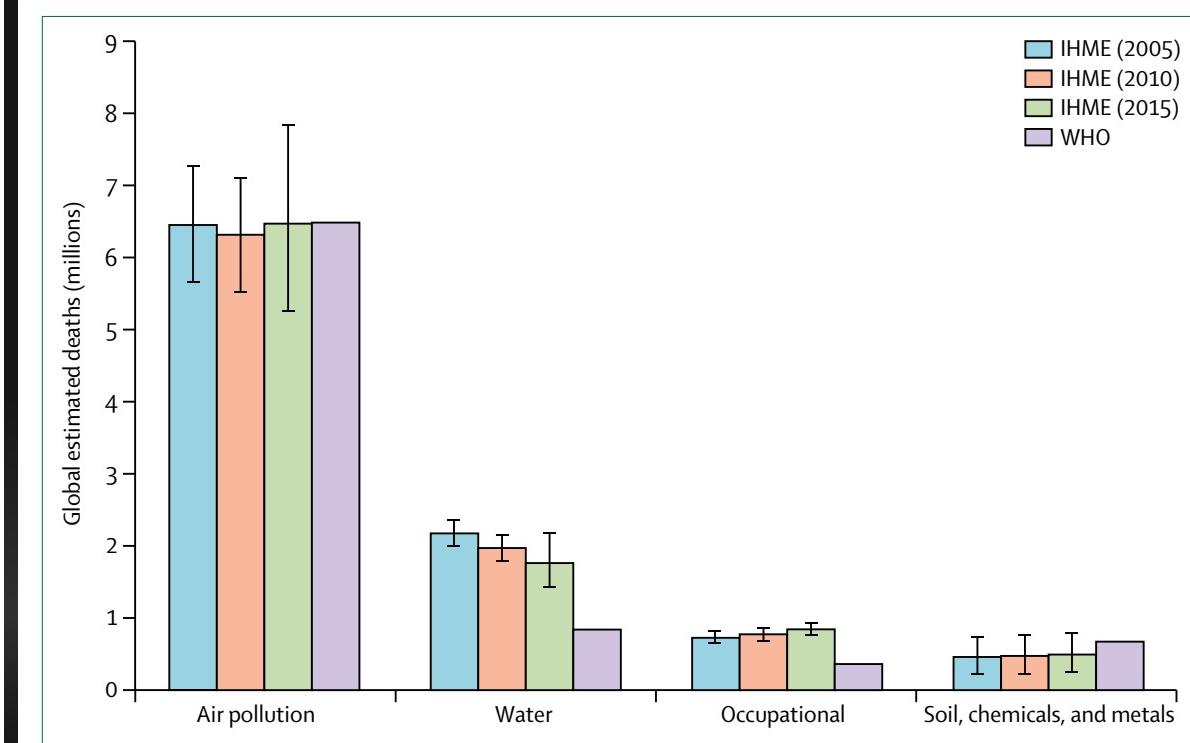
Atmospheric Chemistry and Dynamics Laboratory: Bryan Duncan,  
Melanie Follette-Cook, Junhua Liu, Julie Nicely

# Why we care about air quality



**Figure 5: Global estimated deaths by major risk factor and cause, 2015**

Using data from the GBD Study, 2016.<sup>41</sup>



**Figure 4: Global estimated deaths (millions) by pollution risk factor, 2005–15**

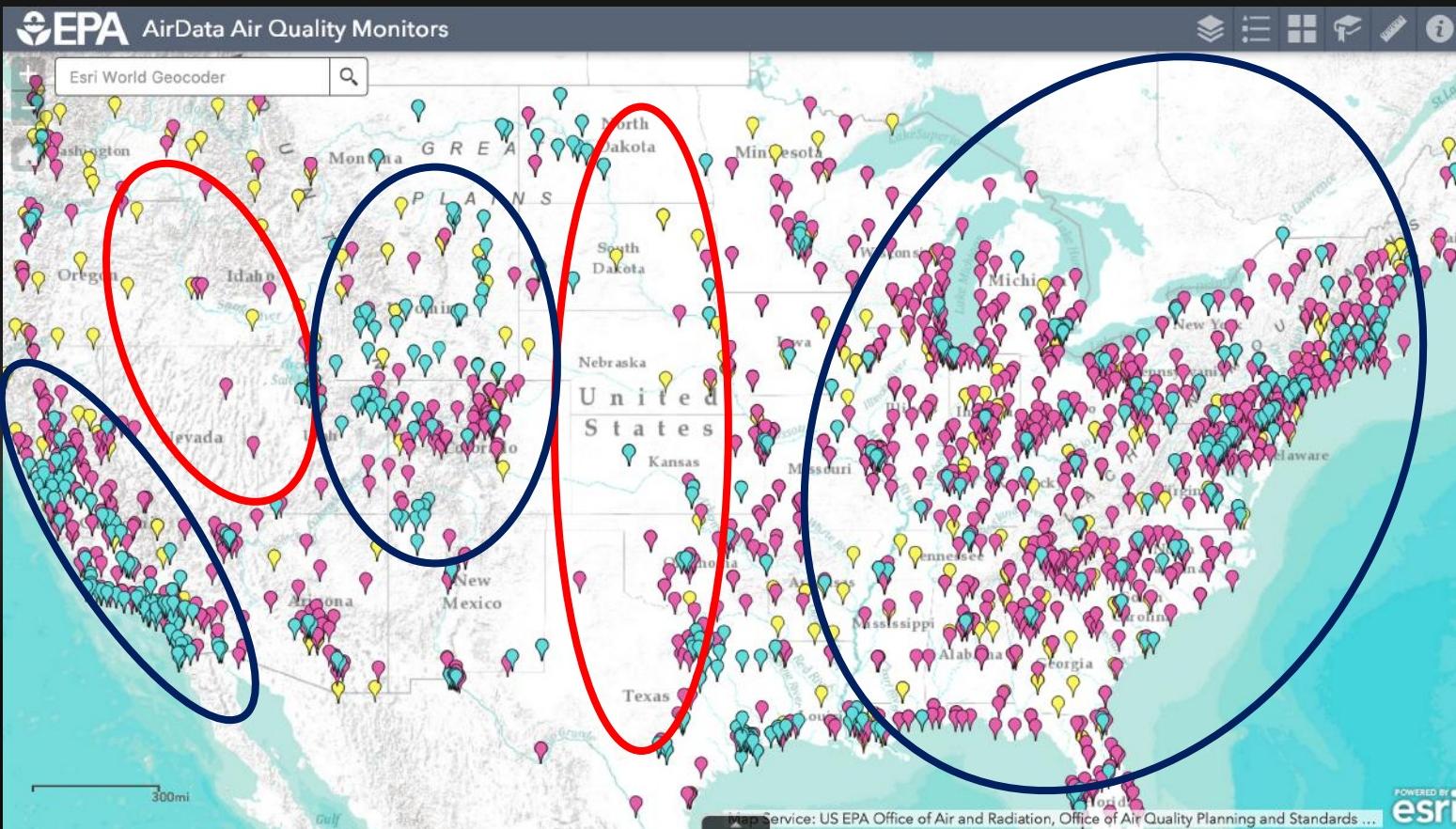
Using data from the GBD study<sup>42</sup> and WHO.<sup>99</sup> IHME=Institute for Health Metrics and Evaluation.

The Lancet Commissions, 2017

# Why do we need models?

Surface observations of pollutants are point source measurements which can be **sparse**.

<https://epa.maps.arcgis.com>

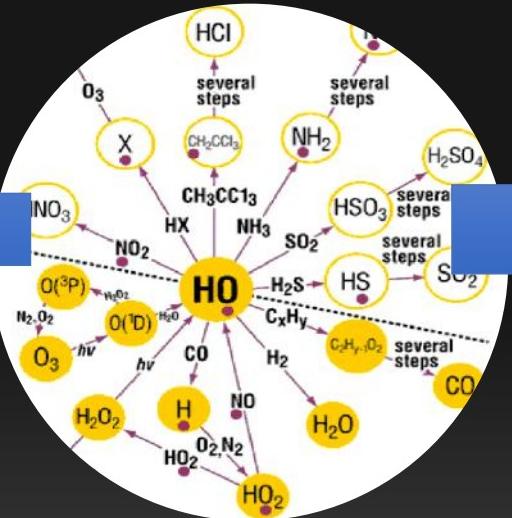
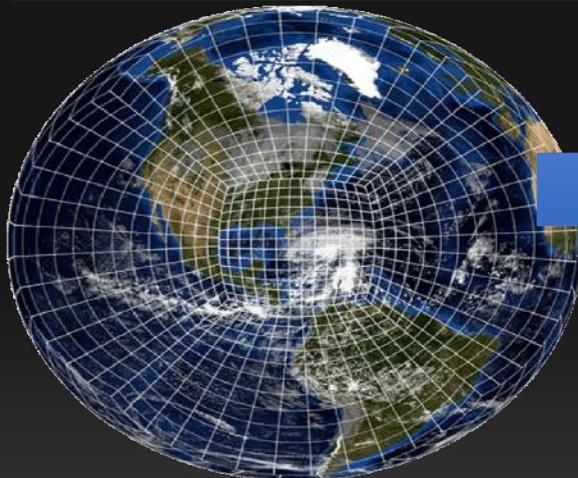


$O_3$   
 $PM_{2.5}$   
 $NO_2$

# Composition forecasting system (GEOS-CF)

Running since March 2017 (still in test mode)

NASA GEOS Earth  
System Model



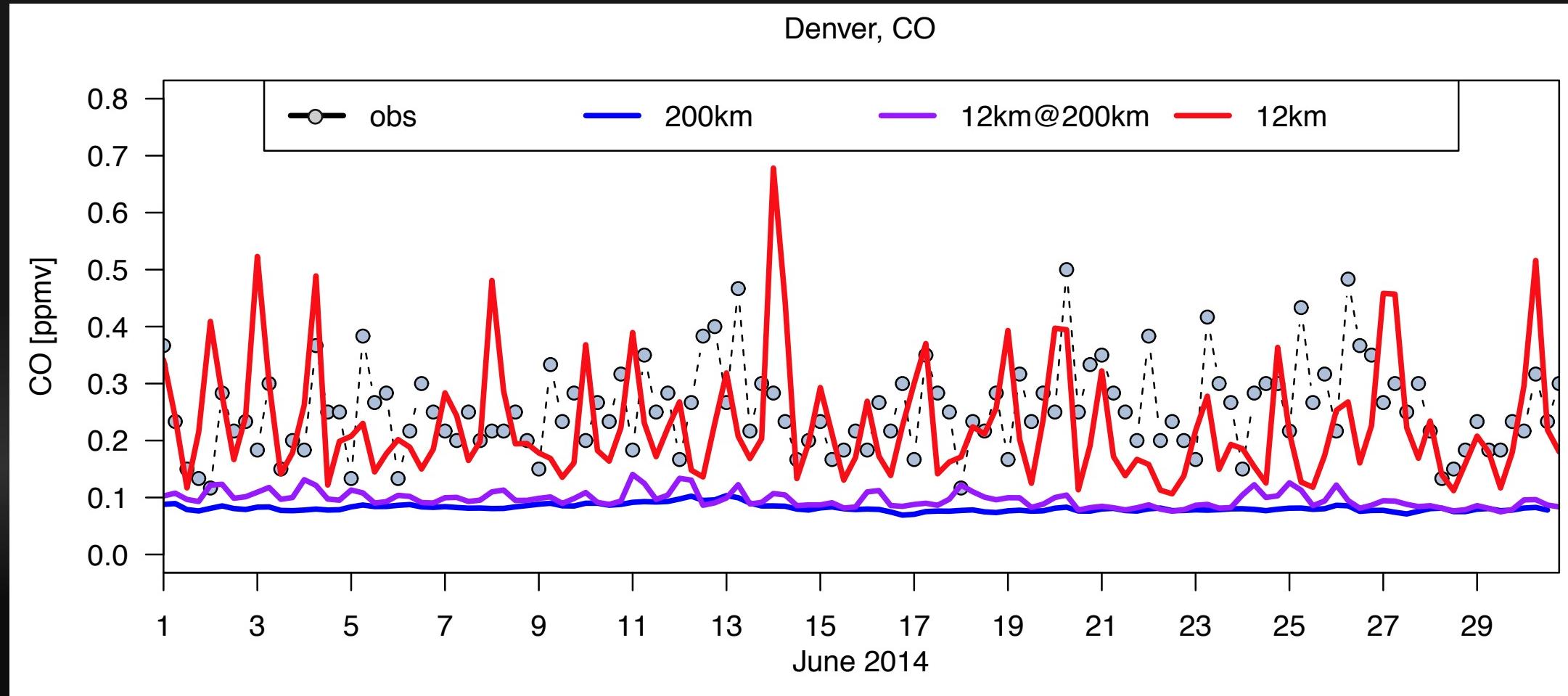
GEOS - FP

GEOS - Chem

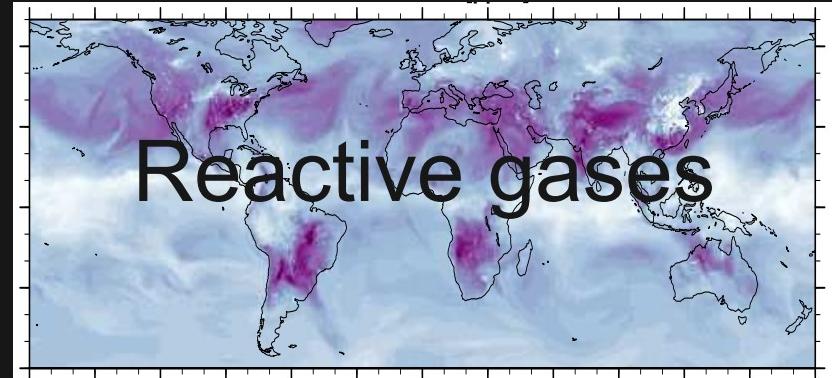
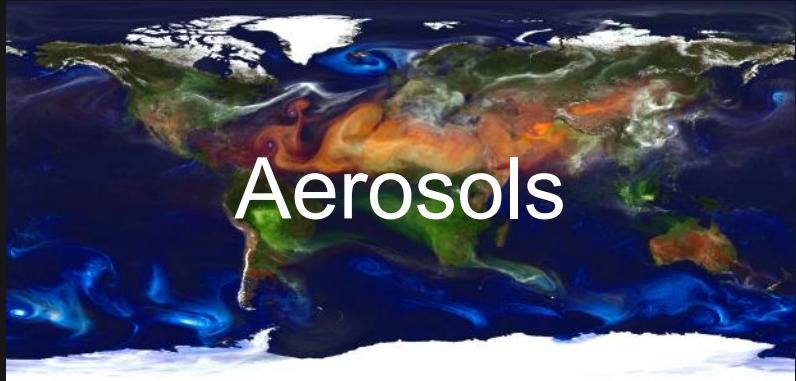
GEOS - CF

- 1-day analysis
- 5-day forecast
- $O_3$ ,  $NO_x$ , VOCs, PM ...
- c360 resolution ( $0.25^\circ$ )

# Higher resolution critical to resolve features relevant to air quality



# Contributors to Air Pollution



- Particulate matter (PM):
  - Organic Carbon
  - Black Carbon
  - Sea salt
  - Nitrate
  - Sulfate
  - Dust
- Ozone ( $O_3$ )
- Nitrogen dioxide ( $NO_2$ )
- Sulfur dioxide ( $SO_2$ )
- Volatile organic compounds (VOCs):  
e.g., Formaldehyde, Benzene, Toluene, and many more...

GOCART

GEOS-Chem

# Health Air Quality Index (HAQI or AQHI)

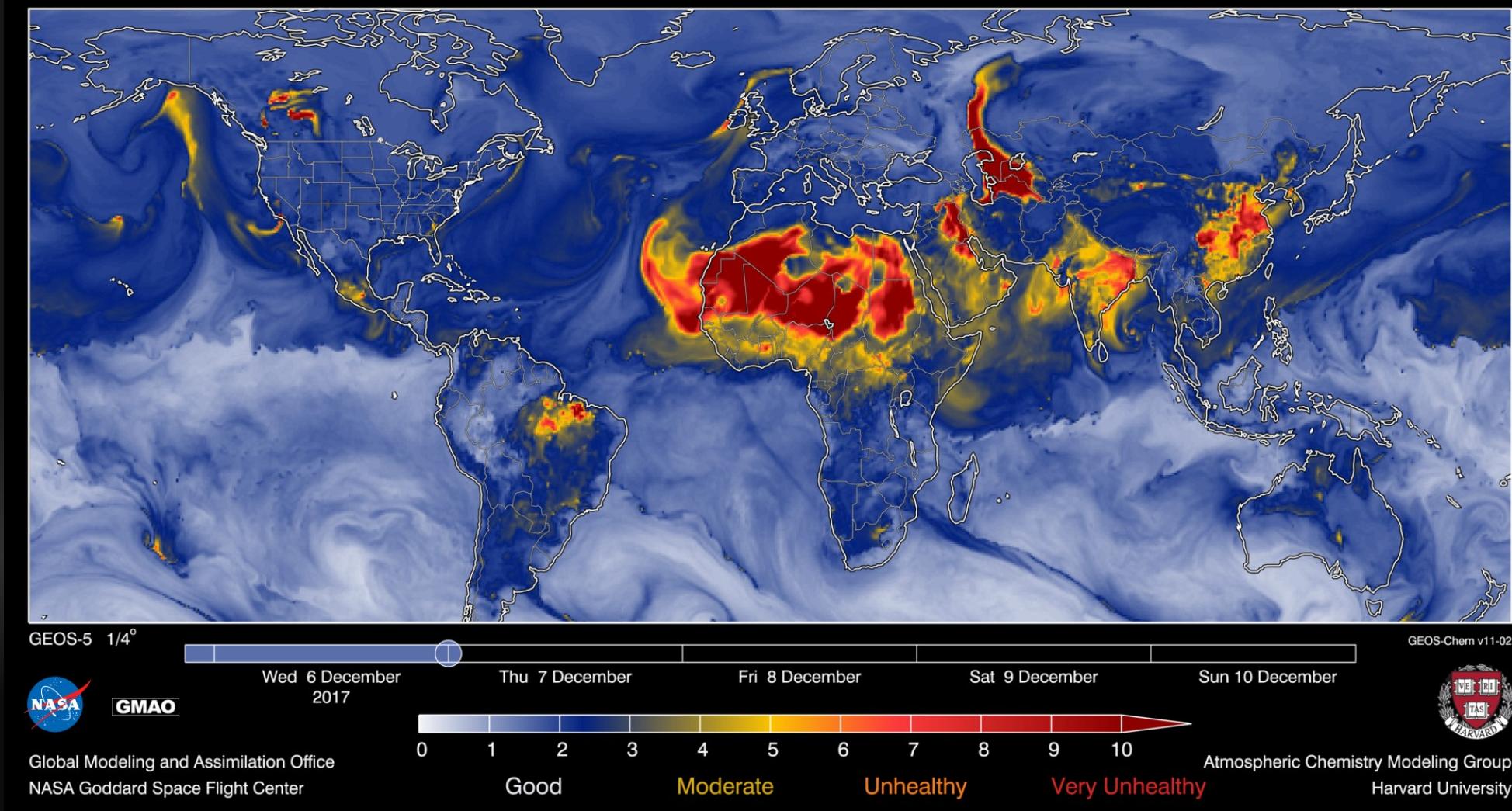
- HAQI is a function of  $\text{PM}_{2.5}$ ,  $\text{O}_3$ ,  $\text{NO}_2$

$$AQHI = \left( \frac{1000}{10.4} \right) \times [(e^{0.000537 \times O_3} - 1) + (e^{0.000871 \times NO_2} - 1) + (e^{0.000487 \times PM_{2.5}} - 1)]$$

(Stieb et al., 2008, J. Air & Waste Manage. Assoc.)

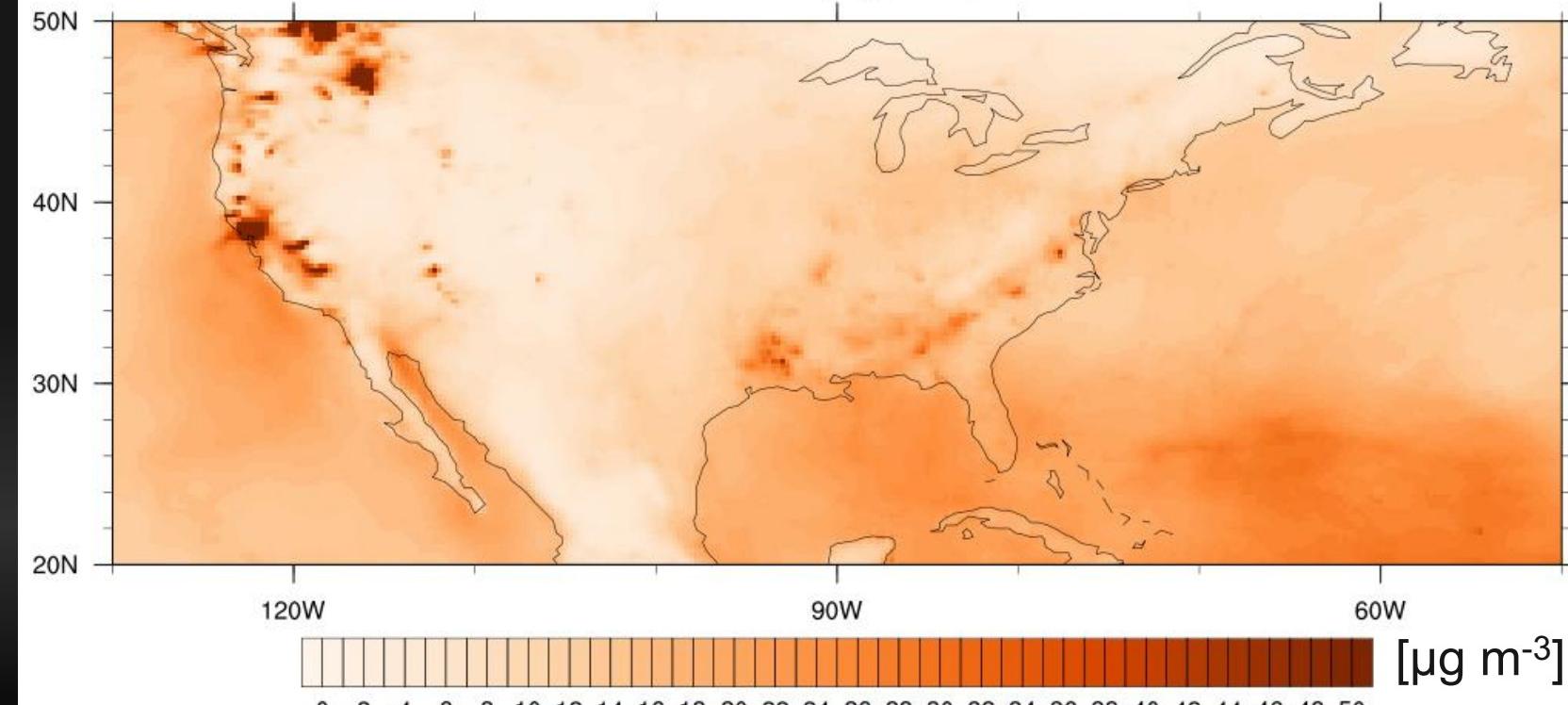
# Health Air Quality Index (HAQI or AQHI)

- HAQI is a function of  $\text{PM}_{2.5}$ ,  $\text{O}_3$ ,  $\text{NO}_2$



# Health Air Quality Index (HAQI or AQHI)

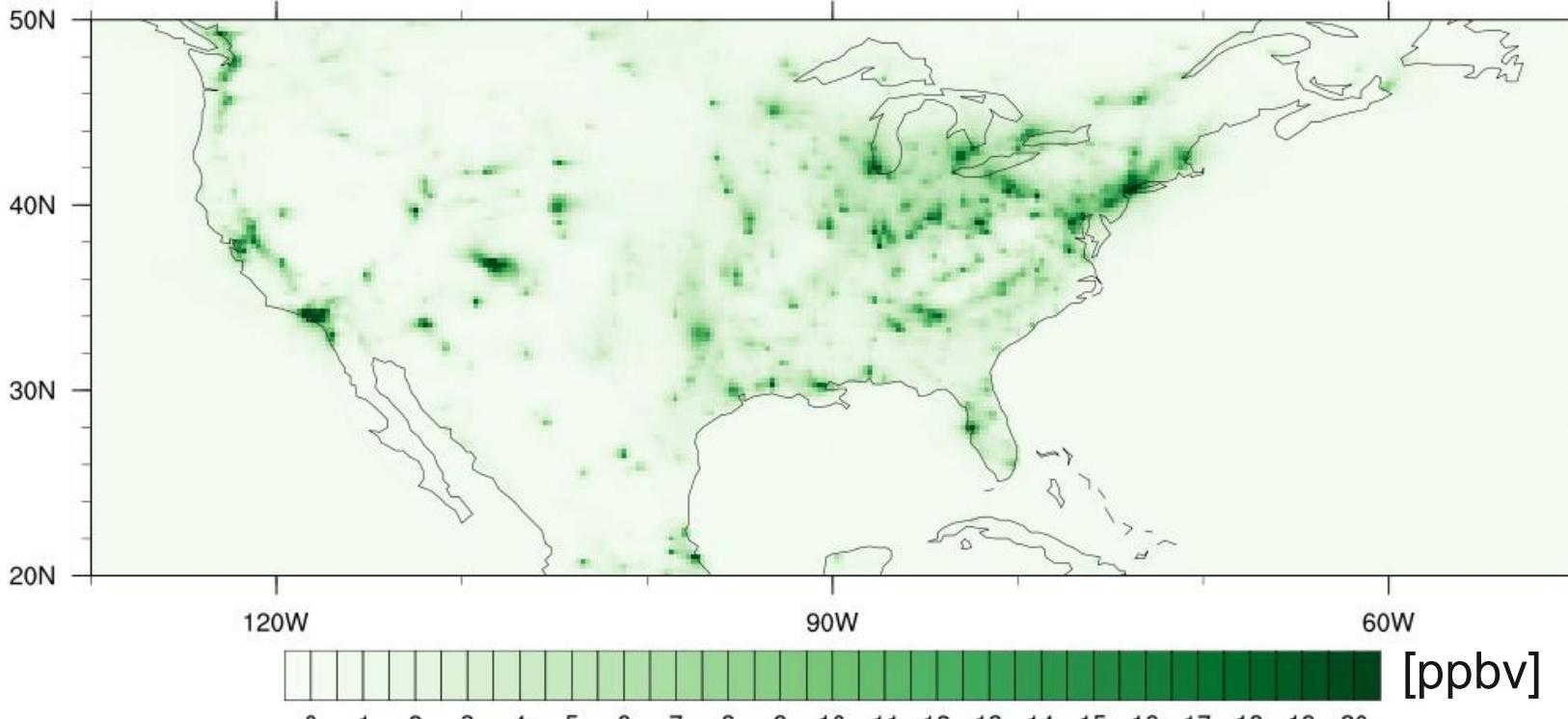
monthly mean PM<sub>2.5</sub>



➤ PM<sub>2.5</sub> driver of spatial gradients

# Health Air Quality Index (HAQI or AQHI)

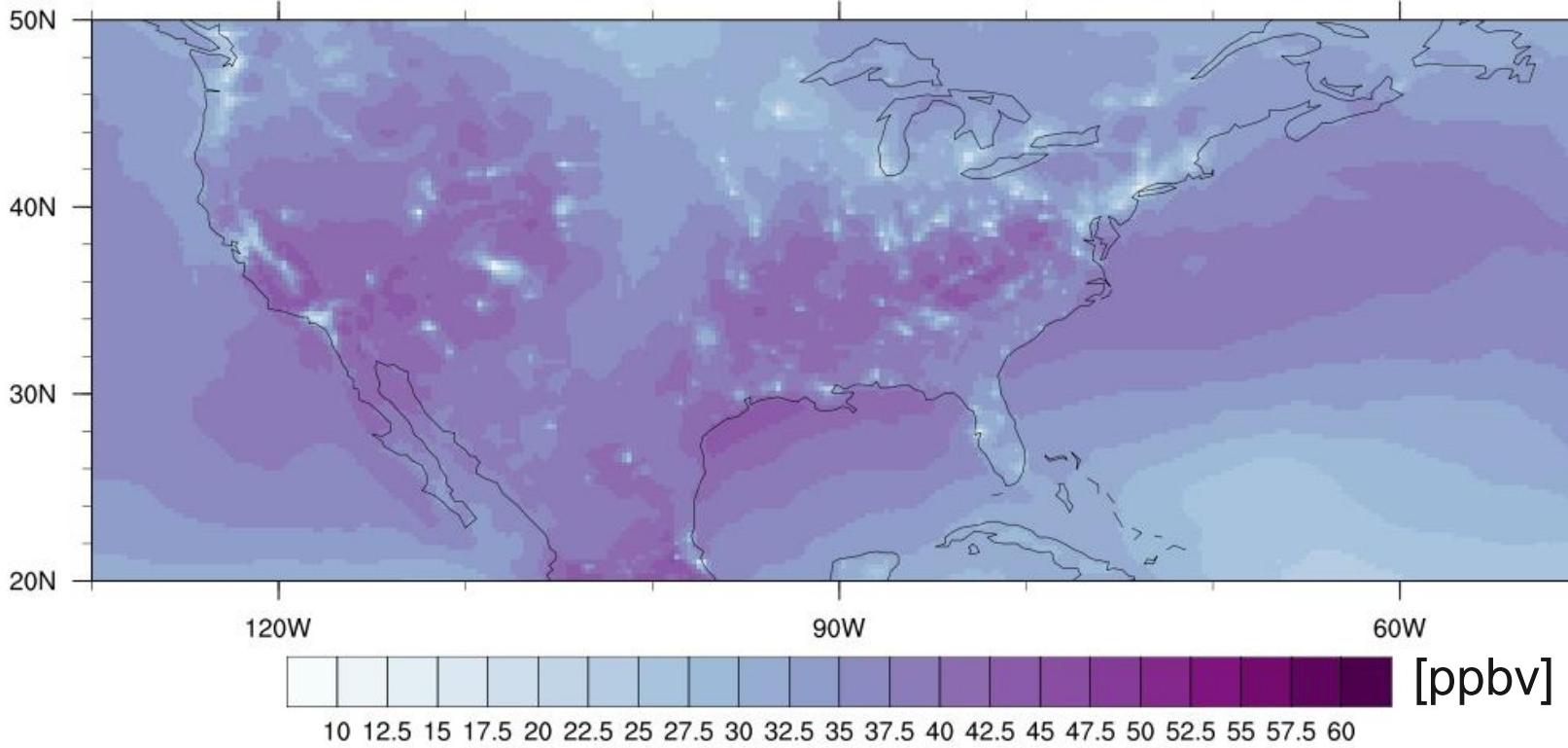
monthly mean  $\text{NO}_2$



- $\text{PM}_{2.5}$  driver of spatial gradients
- $\text{NO}_2$  is Short-lived
- Extreme gradients

# Health Air Quality Index (HAQI or AQHI)

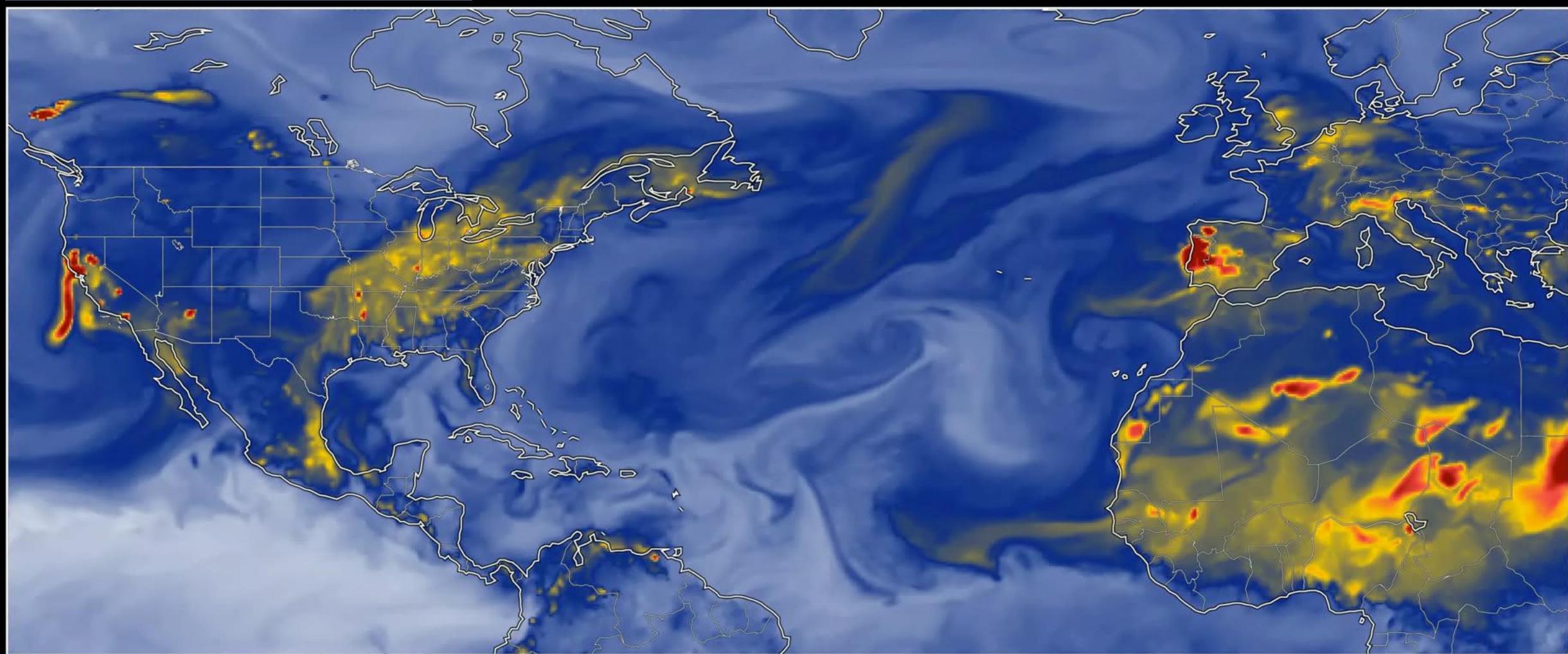
monthly mean  $O_3$



- PM<sub>2.5</sub> driver of spatial gradients
- NO<sub>2</sub> is Short-lived
- Extreme gradients
- O<sub>3</sub> influences Background levels

HAQI = f(NO<sub>2</sub>, PM<sub>2.5</sub>, O<sub>3</sub>)

## Health Air Quality Index



GEOS-5 1/4°



10 October  
2017



GMAO

Global Modeling and Assimilation Office  
NASA Goddard Space Flight Center



Moderate

Unhealthy

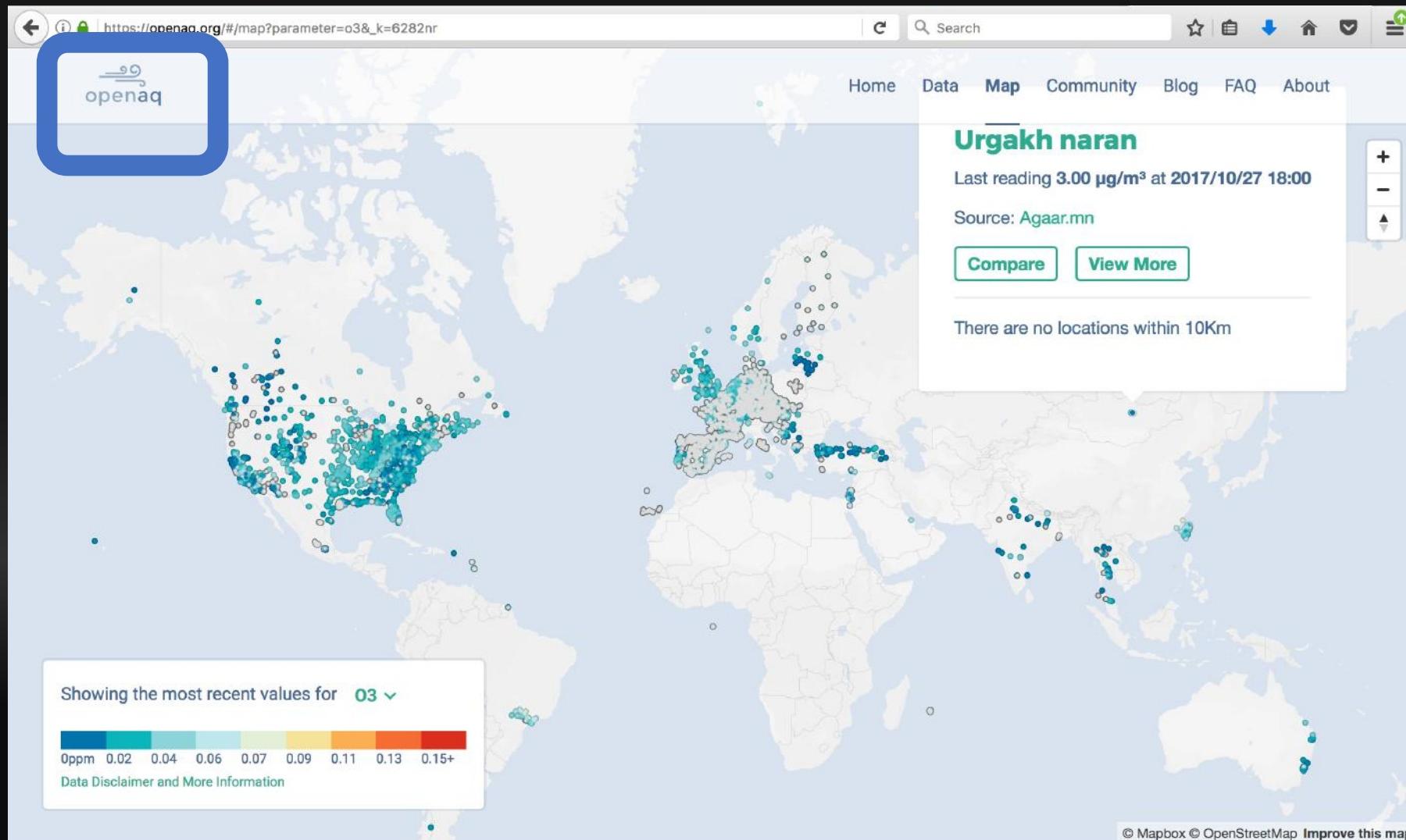
Very Unhealthy

GEOS-Chem v11-02



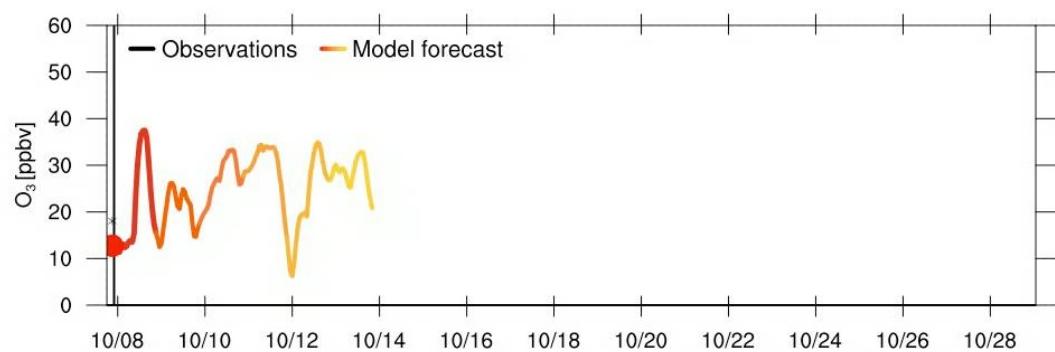
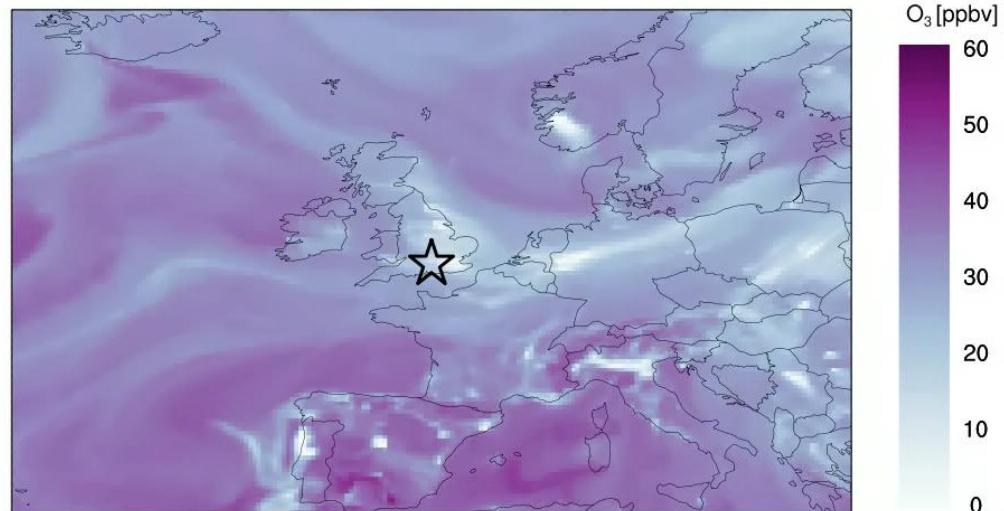
Atmospheric Chemistry Modeling Group  
Harvard University

# OpenAQ surface observation data base

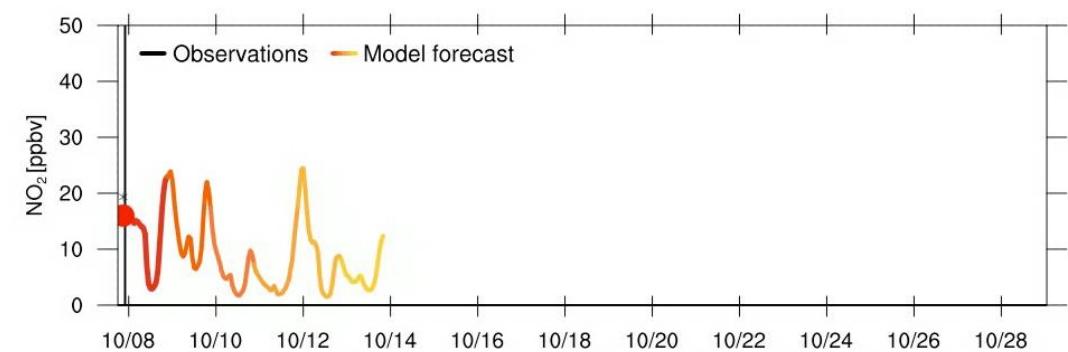
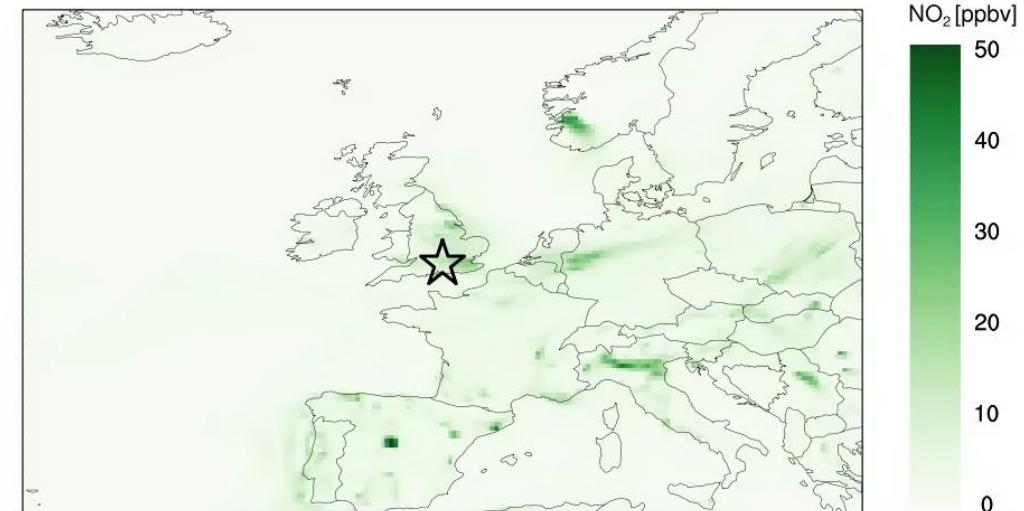


# Observations vs. Model Forecast

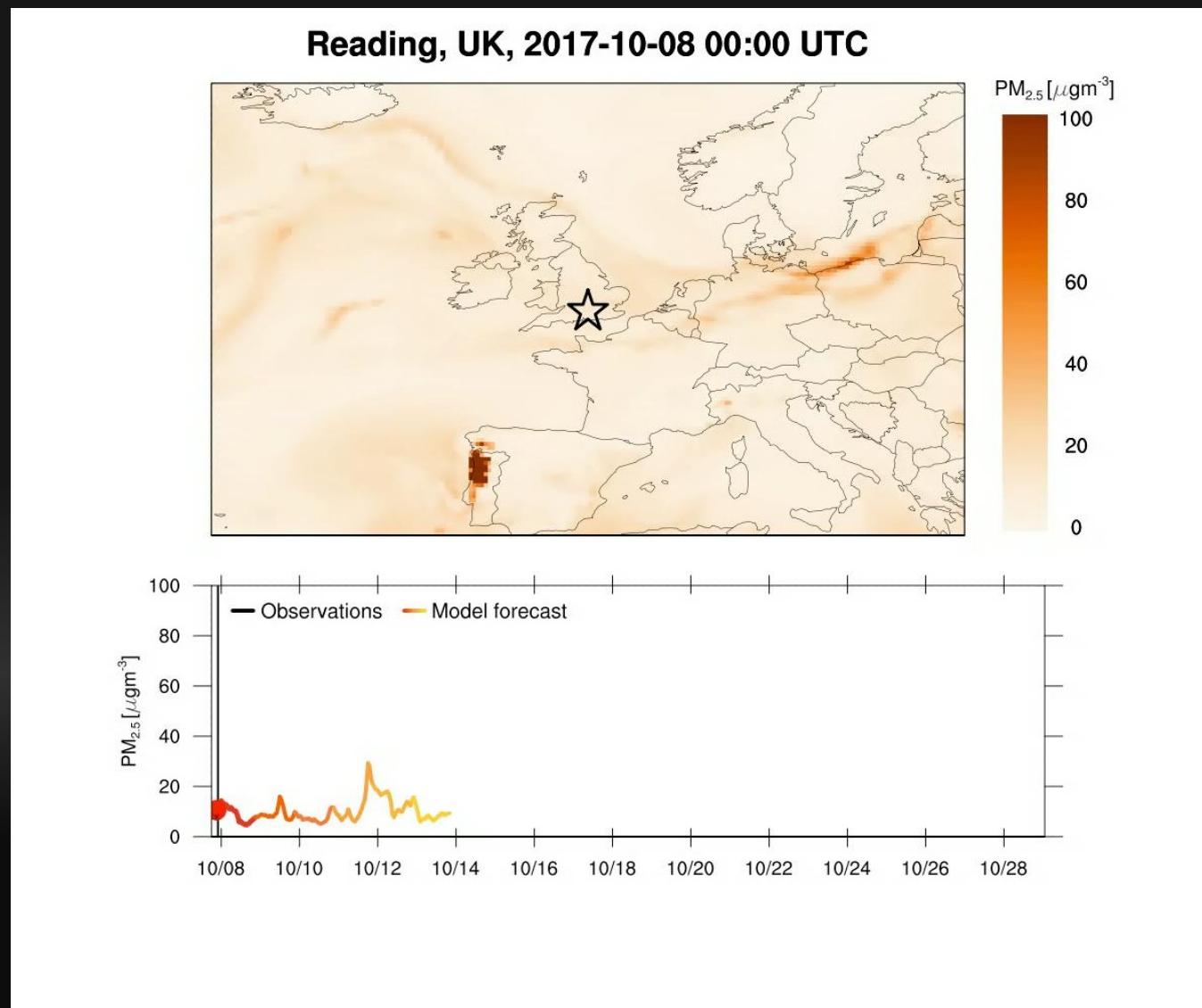
Reading, UK, 2017-10-08 00:00 UTC



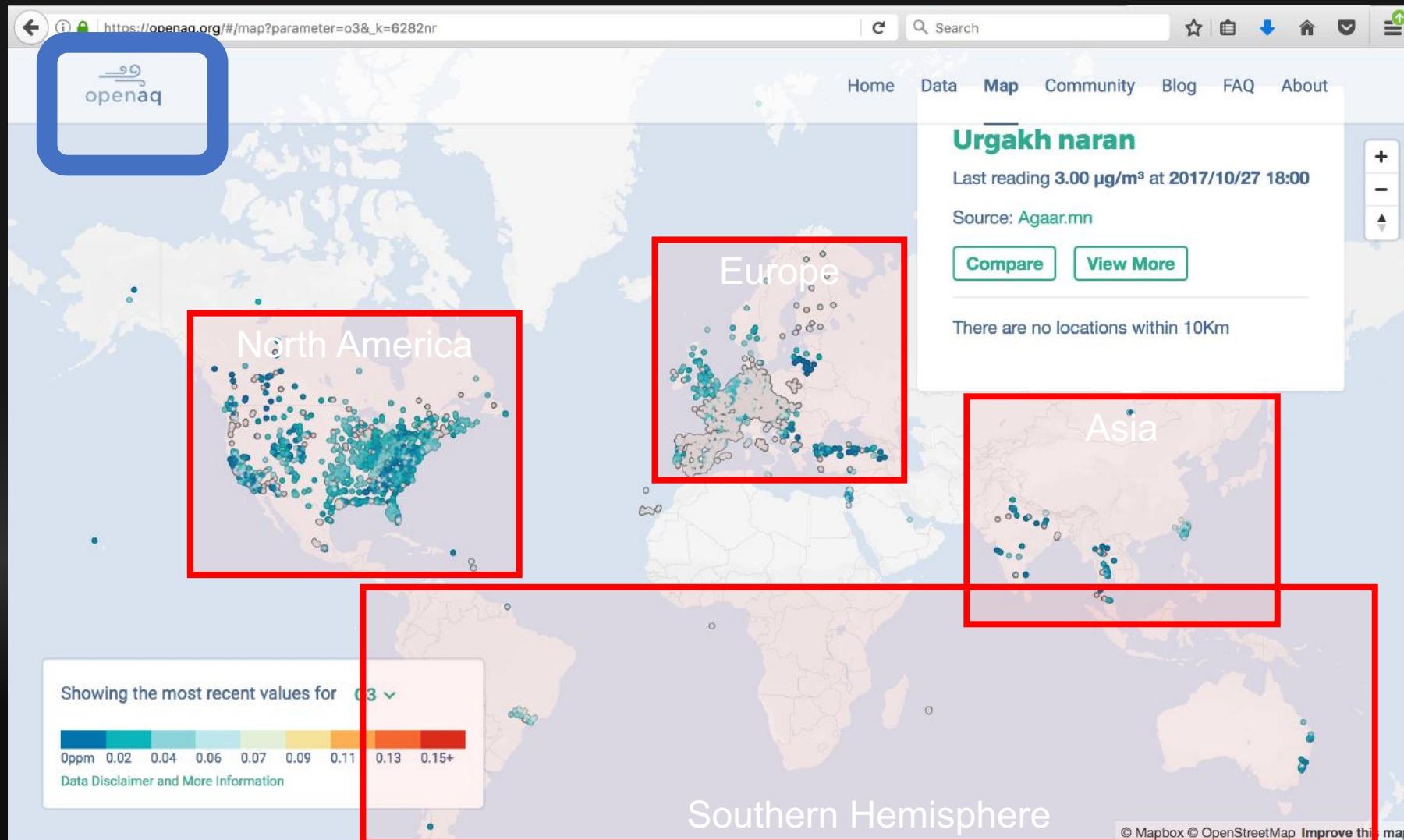
Reading, UK, 2017-10-08 00:00 UTC



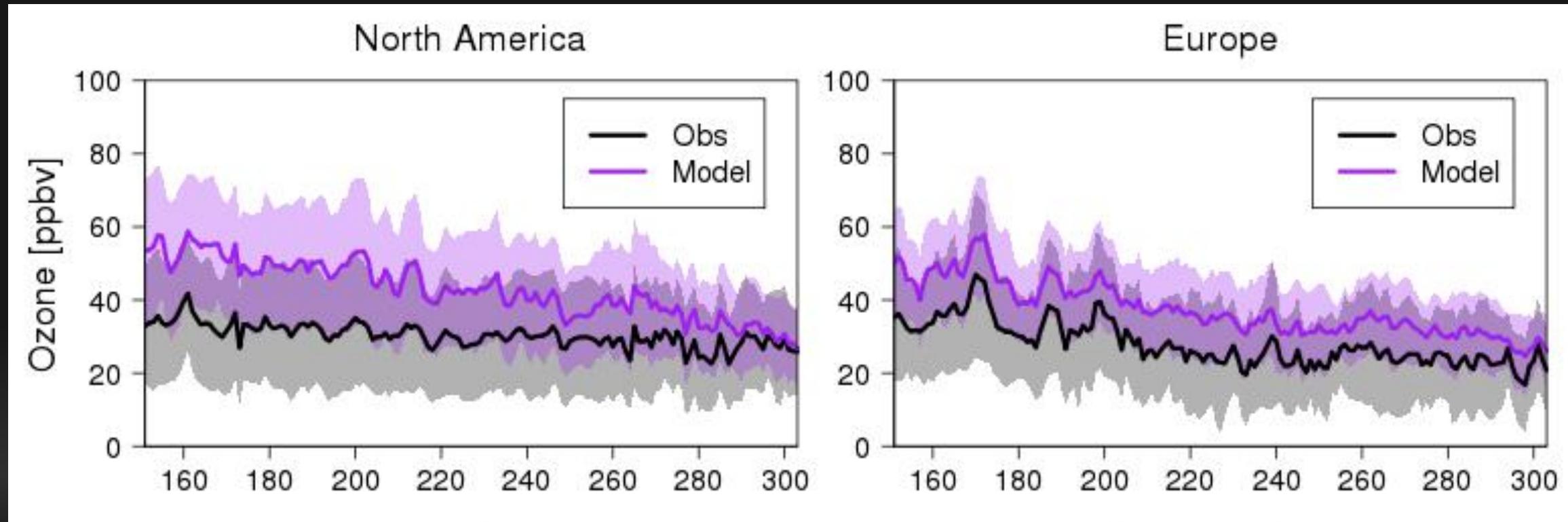
# Observations vs. Model Forecast



# OpenAQ surface observation data base

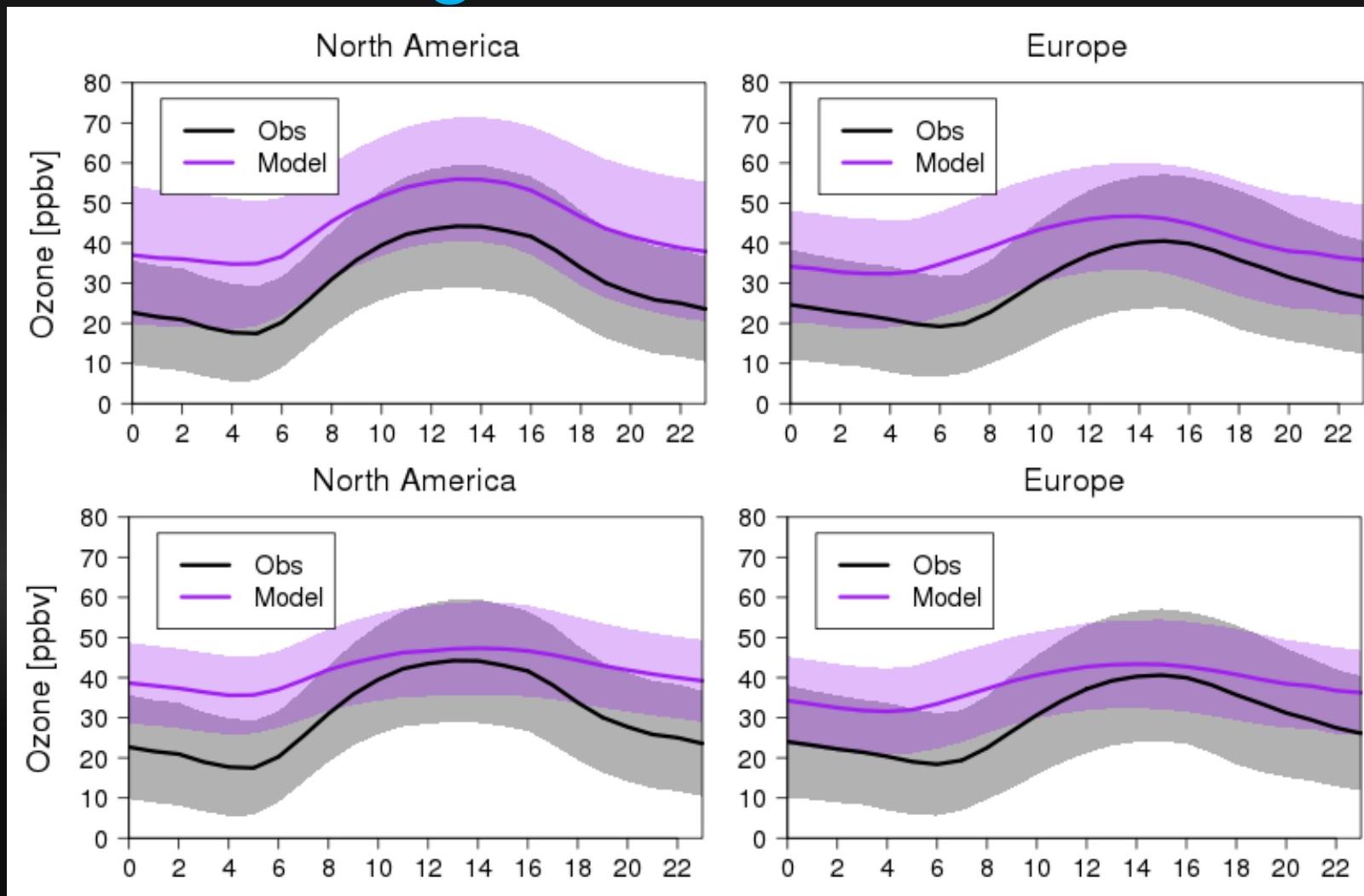


# Surface O<sub>3</sub> observations compared to GEOS CF



# Diurnal cycle of surface O<sub>3</sub> is reproduced at the higher resolution

0.25°

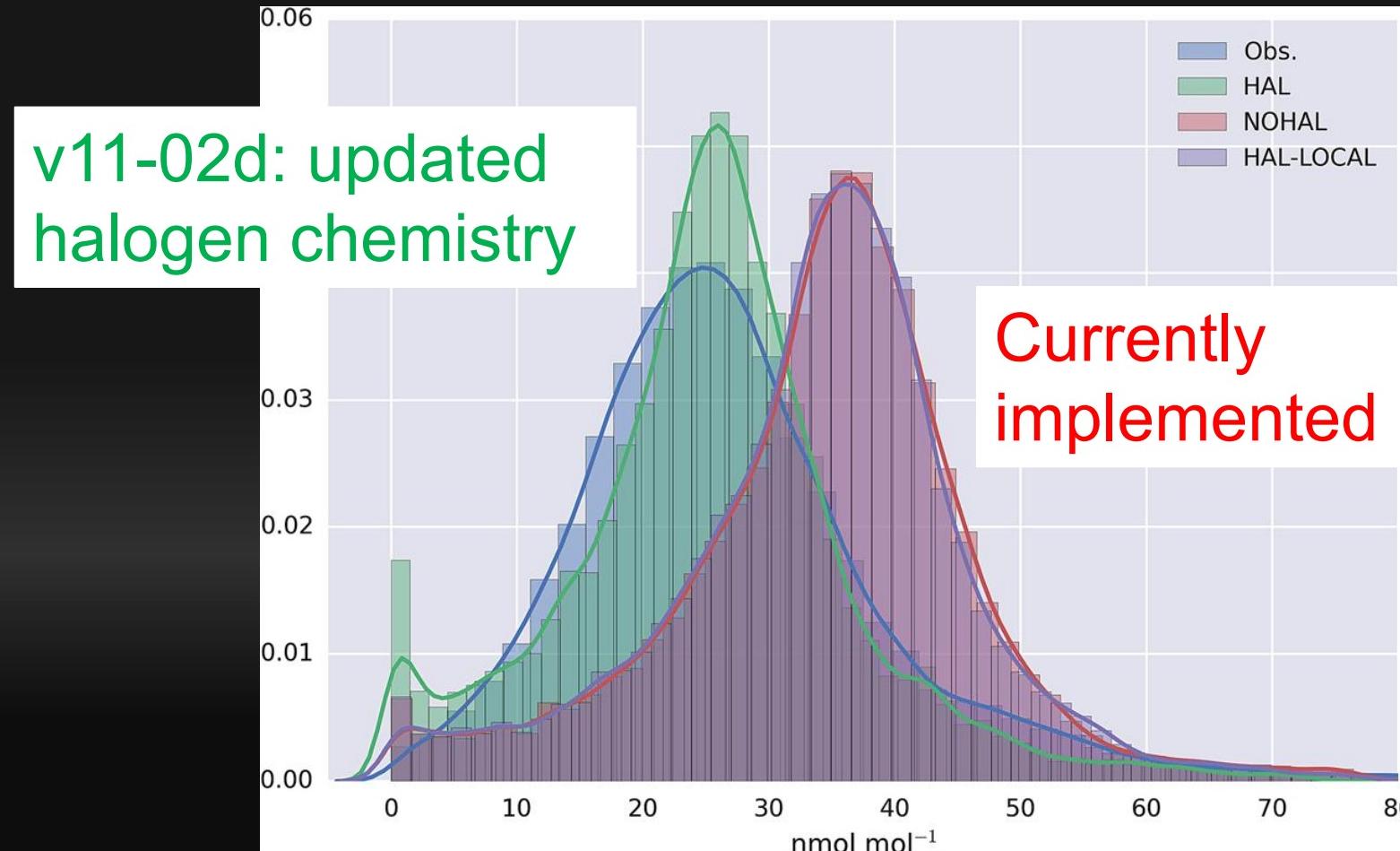




# It is a work in progress....

- Ongoing model evaluation / benchmarking
- Implement GEOS-Chem v11-02d

# Current GEOS-Chem version is known to have high surface O<sub>3</sub>





# It is a work in progress....

- Ongoing model evaluation / benchmarking
- Implement GEOS-Chem v11-02d
- Share model output in 2018
  - If interested please email one of us  
[k.e.knowland@nasa.gov](mailto:k.e.knowland@nasa.gov)  
[christoph.a.keller@nasa.gov](mailto:christoph.a.keller@nasa.gov)